MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 2, 2017/2018

EOP 4076 – LASER TECHNOLOGY AND APPLICATIONS

(OPE)

5 MARCH 2018
9.00 a.m – 11.00 a.m
(2 Hours)

INSTRUCTION TO STUDENT

1. This Question paper consists of **6** pages including cover page with **4** Questions only.

2. Attempt **ALL** questions. All questions carry different marks and the distribution of the marks for each question is given.

3. Please print all your answers in the Answer Booklet provided.

Question 1

(a) In a discussion among a group of optical engineers, the effect of laser linewidth narrowing procedure is compared between homogeneously and inhomogeneously broadened lasers. You are asked to provide your evaluation and explanation specifically on which of these two broadenings provide a better total laser power upon linewidth narrowing.

[6 marks]

(b) You are given a choice of two resonator sets to build a laser. The gaps of the mirrors, l and the individual curvature radius, R are shown in Figure Q1b. Analyse both mirror sets to determine which is stable.

[6 marks]

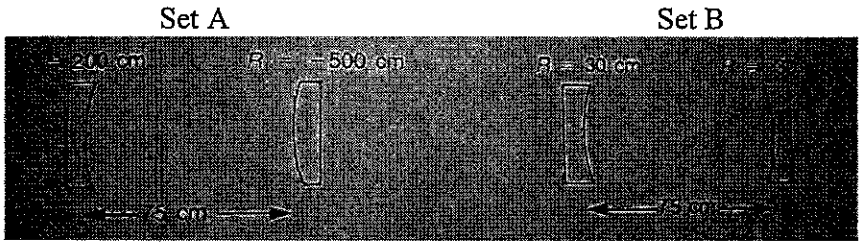

Figure Q1b: Resonator configurations.

(c) In an experiment on a laser using a crystal host with an index of refraction, n of 2.0, the laser emitted at line centre, λ_{ul} of 700 nm with a homogeneously broadened linewidth, $\Delta\nu^H$ of 61.2 THz. You identified that the radiative transition probability, A_{ul} of the laser transition was 10^4 s^{-1}. The formula for the stimulated emission cross section for the homogenously broadened medium is given below.

$$\sigma_{ul}{}^{H} = \frac{\lambda_{ul}{}^{2} A_{ul}}{4\pi^2 n^2 \Delta\nu^H}$$

Calculate the population density difference ΔN_{ul} that would be required to produce a gain coefficient value of 9.21 m^{-1}.

[5 marks]

Continued...

Question 2

(a) After evaluating a laser system, you noticed that the host material had poor optical qualities and poor mechanical/thermal properties. Describe the potential undesired consequences of using this kind of host material.

[6 marks]

(b) You are assigned to evaluate a Carbon Dioxide laser with a longitudinal discharge that operates at high total gas pressure. Prepare a brief evaluation report stating one(1) advantage and two(2) disadvantages of this particular structure and condition.

[6 marks]

(c) During inspection of an Argon ion laser, you concluded that in order to optimise its operation, a cooling system and an axial magnetic field are needed to be incorporated. Provide the reason for your conclusion above.

[6 marks]

(d) A hypothetical laser rod of length 0.15 m and diameter 5 mm is coated with a 100% reflector at one end of the rod and no reflector at the other end (it has an antireflection coating on that end). It operates at a wavelength of 800 nm and is homogeneously broadened. The upper laser level has a lifetime of 200 μs. The pumping flux is such that the laser is at threshold, and the population difference between the upper and lower laser level for that condition is measured to be 1×10^{26} m^{-3}. What is the intensity of the laser at the output end of the rod?

[7 marks]

Continued...

Question 3

(a) (i) In laser marking, either using computer-controlled mirrors or reflective mask can be utilized. Compare the two approaches by providing one advantage and one disadvantage, respectively.

[4 marks]

(ii) In the reflective mask approach, suggest two methods to shine a laser onto the reflective mask.

[2 marks]

(b) Shielding gas is commonly used in laser welding. Explain its purpose, and propose a beam head design for the shielding gas (with a suitable sketch and proper labelling).

[5 marks]

(c) Lasers have been proven useful in scribing silicon wafers. Analyse the problem in the conventional method of using diamond point, and highlight the major advantage of using lasers.

[6 marks]

(d) In a laser welding facility, a pulsed Nd:YAG laser is used with a gain rod of length 0.1 m and diameter 8 mm. The gain rod is flashlamp pumped and is measured to have a single-pass gain (I / I_0) of 5 at the laser wavelength of 1.06 μm. The pumping duration and thus the output pulse is several hundred microseconds, so we may think of it as a quasi-continuous beam. The rod also has measured scattering losses per pass of 0.5%. Mirrors are installed at each end of the rod. Assume the laser beam is the same diameter as the laser rod. The saturation intensity, I_{sat} is 2.91×10^7 W/m^2.

(i) What would be the optimum transmission for the output mirror if a high-reflecting mirror is used at one end of the cavity and the output mirror at the other end?

[4 marks]

(ii) What would be the output power with this mirror combination?

[4 marks]

Continued...

Question 4

(a) In a wire diameter measurement system, a Helium-Neon laser with a wavelength of 632.8 nm is utilized. The laser has a gain length of 0.2 m installed in a two-mirror cavity having mirror reflectivities of 99.9% and 98%. Assume that there are scattering losses of 0.2% per pass within the cavity.

(i) Evaluate the single-pass gain in the laser tube if the discharge current is sufficiently high for the gain to be four times of its lasing threshold value

[4 marks]

(ii) During an experiment, a measurement of 3.13 μm is recorded for the diameter of a wire. What is the corresponding angle of the first spot observed from the direction of the laser?

[3 marks]

(iii) By stating relevant formulas, analyse the change of the distance between adjacent spots for the situation when the wire is put closer to the screen and the situation when the wire diameter is larger, respectively.

[6 marks]

(b) An equilateral triangular ring Helium-Neon laser gyroscope operates at a wavelength of 632.8 nm with a total cavity power of 199 mW. Assume that the beam diameter is 1 mm inside the laser cavity and that the power is uniform over the beam cross section. The laser linewidth of the Helium-Neon 632.8-nm transition is 1.5×10^8 Hz. When, the ring laser is rotated about its centre axis which is perpendicular to its ring plane at a rate of 30° per hour, the beating frequency is measured to be 10 Hz

(i) Draw and describe the conceptual structures of the ring laser gyroscope.

[5 marks]

(ii) What is the ratio of the stimulated emission rate to the spontaneous emission rate for the laser at the given operating wavelength?

[10 marks]

(iii) Determine the length of any one side of the ring laser.

[5 marks]

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Appendix A

Physical Constants and Units

Constant	Symbol	Value (mks units)
Speed of light in vacuum	c	3×10^{8} m/s
Electron charge	q	1.602×10^{-19} C
Boltzmann's constant	k_B	1.38×10^{-23} J/K
Permittivity of free space	ε_0	8.8542×10^{-12} F/m
Permeability of free space	μ_0	$4\pi \times 10^{-7}$ N/A^2
Electron volt	eV	1 eV = 1.602×10^{-19} J
Planck's constant	h	6.626×10^{-34} J·s

End of paper